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UVSP & Complimentary Data Anal. & Modeling

The University
Of Alabama
In Huntsville

Final Report
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We have studied several data sets obtained by the UVSP and HXIS instruments on board SMM. These studies included a large amount of data that we cannot explicitly describe here for sake of brevity. From these data we selected several events or sequences of events that are specially representative of the plethora of active region energetic phenomena that was simultaneously observed by UVSP and HXIS. The selection criteria was to have available both types of observations in active region flares that are not too bright that the UVSP instrument was switched off for protection, and at the same time flares that are not too dim in X-Rays so that HXIS will have collected significant data. Another criteria of secondary importance was to select events where auxiliary optical data is available. We selected three sequences of events:

1) The June 15, 1980, event is basically a compact miniflare not far from disk center where H alpha data was available from Meudon Observatory. There is a number of related minor events around this miniflare, such as remote brightening, arches and a high velocity event, but there are no large ejections of material. These kind of events are typically related to the development of included polarities in the periphery of large sunspots. This makes them a different class of those occurring in the included polarities away from big spots. The last class of events usually develop large "flaring arches" that are not observed in the June 15 and similar events. In these events the interaction between the confined flare and the large scale field is much more limited. In the short duration of this contract we were able to finish up the quantitative analysis of the June 15 events. The results have been published in Astrophysical Journal, 424, p. 1022-1031 (April 1994) that we enclose. Summarizing them we find that the data is consistent with a number of small loops, of about 2000 km length, that originate in the included bipole at the edge of the big leading sunspot of a mid-latitude active region. These loops heat up to temperatures of several tens of million degrees, and have very high pressure transition regions at their feet. The energy released in the loops is partially radiated directly by the high pressure plasma, but a substantial fraction is conducted downwards through the feet and that explains well the observed UV emission in this event. The H alpha and the UV indicates no important velocities in this event, and consequently, any evaporation that may have occurred should have taken place very fast and was not observed. It is, however, noticeable that energy (not mass) spilled over a larger region that displayed some brightening in H alpha. This energy may have been transferred by streams of energetic particles (small particle fluxes of very energetic particles), or by traveling magnetic disturbances. In either case they are small spill-over relative to the event energy. This energy was estimated of the order of 10^{28} ergs, and this event was preceded and followed by a number of smaller events (energies in the range 10^{25} - 10^{26} ergs) that do not seem to originate or be originated by the miniflare we study. Rather these events seem as independent consequences of the overall

evolution of the small-scale magnetic field. We refer to the attached paper for more details on this topics

2) The events on March 27, 1980, provided one of the most striking images obtained by the UVSP. In this image a group of loops is seen in the C IV line at several hundred thousand kilometers above the limb. These loops display a very clear velocity pattern that indicates downflow from the top towards both feet. In many respects these loops are similar to the decay phase of the flaring arches that is also observed in UV lines (as well as in H alpha). However, here we did not observe the injection of material from one of the feet, that in the flaring arches constitutes the buildup phase. We were able to locate H alpha data that confirmed that, similarly to the flaring arches, cooler loops were also present in these arches. Also, we found out that the arches resulted after a miniflare that was well observed both in C IV and in X-rays many minutes before. We studied this miniflare at the limb, and determined the energy emitted in C IV and in X-rays, that is again of about 10^{28} ergs. The fact that this energy is similar to the June 15 event is not a coincidence, but just a selection effect because brighter flares cannot be observed in C IV, by UVSP, and dimmer flares cannot be very well observed in X-Rays, by HXIS. In spite of having similar energy this event has much more significant dynamics associated. This dynamics is well seen as very fast ejections of material (several hundreds of kilometers per second) in streams that originate from the miniflare and fly along special paths. These ejections were for the most part relatively cool, but narrow and were well observed in CIV ($\sim 10^5$ K) and not in X-Rays or in H alpha. We believe that if Lyman alpha observations of the event were available they should have shown also these cool but narrow jets. These jets last a few minutes after the flare, but they do not feed the material needed for the large loop system, that we mentioned previously, because all the jets are pointed to the South direction and none has the path of the large loop system. Instead, we do observe a significant (but noisy) X-Ray signature just after the miniflare at the locations of the loop system but well before it is observed in CIV and H alpha. Therefore, we conclude that in contrast with the case of the "flaring arches", where the injection of material into the loops is observed simultaneously in the temperature range 10^4 - 10^7 K (from H alpha to X-Rays), in the case of March 27 events we are observing something closer to the typical "post-flare loops" in which the material is injected at very high temperature and is only visible in X-Rays. In the post-flare loops it is usually observed in H alpha that later after the flare cool material suddenly appears and flows towards the feet of the loop system. Here, we see this apparition and downflow not only in H alpha but also in CIV, before it cools below 10^5 K. From the data we obtain some quantitative measures of the amount of material present in the various features above the limb, and we find that the energy contained in these features is not very significant compared to the energy that is radiated by the flare in X-Rays and UV. This energy radiated is observed right at the solar limb and up to about 4,000 km above the limb. Thus, most of the energy in this event is emitted not by the large magnetic structure, but by the small compact feature at the visible footpoint of the large magnetic arches. A more complete description of the events is in preparation and will be submitted for publication soon.

3) The events of October 20-26, 1980, were selected because they constitute a sample of miniflares that occur in a special magnetic configuration that occurs as a relatively high-

latitude active region interacts with a neighboring coronal hole. This interaction is evidenced by the Kitt Peak magnetograms that show the development of intermingled polarity magnetic fields as a result of the emerging and fragmenting of active region fields. We have studied UV and X-Ray data and we have selected several events, one of them has also been observed in H alpha by the Meudon Observatory. In the event observed in H alpha a surge was found, and this event will be studied in the first place. The study on this events that was included in this contract has been completed and only consisted in the preliminary analysis that we have carried.

In summary we have accomplished all the tasks that were contracted, and we have found very important new information regarding to the occurrence of the frequent miniflares in active regions. We were able to find quantitative estimates of the energy released and how it is dissipated, and we were able to identify the magnetic structure in which they occur and how it affects the way in which the dissipation occurs. Of course, our research indicates directions for future research but by no means exhaust the subject. We would like to continue this research in a more extensive way and carrying more complex MHD modeling of the magnetic process occurring in these events. For this we have identified and very well characterized and quantified the magnetic structure and evolution, including the velocities and time-scales that are relevant. Moreover, we have characterized and quantified the energy dissipation process, and these two give us a very important insight that can make possible a "realistic" MHD modelling of actually observed events. This kind of study goes well beyond the abstract MHD modelling of general cases without proper consideration of the "energy balance". We believe that this energy balance is the key to perform realistic MHD calculations, because otherwise the most important process which one is trying to understand would be missing or improperly treated in the simulations.

We hope to be able to obtain further funding in the future so that we can pursue the "realistic" modelling of the magnetic energy dissipation in the solar atmosphere by using MHD analysis and simulations based on actually observed magnetic structure and evolution, and on a proper treatment of "energy balance" using sophisticated calculations supported by observations such of those by UVSP and HXIS.

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